

1                                   **“PROPELLANT TREATMENT**  
2                                   **AND CONTINUOUS FOAM REMOVAL OF WELL DEBRIS”**

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4                                   **CROSS REFERENCE TO RELATED APPLICATION**

5                                   This application is a continuation-in-part of pending US Patent  
6 application Serial No. 10/650,709 filed on August 29, 2003, the entirety of which is  
7 incorporated herein by reference.  
8

9                                   **FIELD OF THE INVENTION**

10                                  This invention relates to a method and apparatus to stimulate a well  
11 through ignition of a propellant in a well adjacent openings such as perforations and  
12 then to immediately thereafter circulate foam for removing blockage material from an  
13 underground formation.  
14

15                                  **BACKGROUND OF THE INVENTION**

16                                  The primary bottlenecks to the production of hydrocarbons from a well  
17 is the inflow rate from the hydrocarbon formation into the wellbore. The inflow is  
18 affected by near wellbore condition and formation characteristics. The near wellbore  
19 conditions and the formations of damaged wells can be positively influenced, with  
20 increased hydrocarbon production, through stimulation treatment. Methods for well  
21 stimulation include, but are not limited to, treatments with various chemicals,  
22 hydraulic fracturing where liquids are injected under high pressure (usually with  
23 propping agents), methods in which explosives are detonated within the formations  
24 to effect mechanical fracture, and combinations of the above procedures.

1 Oil and gas wells are subject to many ailments, some of which are  
2 treatable. One such ailment is a blockage of perforations resulting in dramatic or  
3 catastrophic decline in production. Some formations, such as an unconsolidated  
4 formation contain fines, such as sand, which flow into the perforation and become  
5 trapped, creating a plug or blockage in the perforation. Other examples of  
6 blockages, or bridging, are perforation debris, clays, silts, asphaltenes, drilling  
7 damage, and foreign or manmade objects. It is therefore desirable to remove these  
8 blockages from the perforations.

9 One such method is described in US patent 4,617,997 to Jennings, Jr.  
10 which teaches a method to create or enhance fractures in a formation and extending  
11 these fractures with foam generated downhole. A foaming agent is mixed with an  
12 aqueous fluid and placed into the wellbore fluid, the level of the wellbore fluid being  
13 above the perforations and productive interval of the formation. A propellant housed  
14 in a canister, which is attached to a retrievable wire line, is placed next to the  
15 fractures. The propellant is ignited creating heat, gas and pressure while  
16 simultaneously initiating the formation of foam. The foam enters the fractures under  
17 such increased pressure for extending the radial fractures. When the pressure  
18 decreases and the foam collapses, the decreased viscosity of the wellbore fluid  
19 causes any resultant fluid and debris which has accumulated in the fractures to  
20 return into the wellbore. It is not disclosed if or how resulting accumulated and  
21 recovered debris is removed from the wellbore.

22 Another method is taught by Mohaupt in US patent 6,138,753.  
23 Mohaupt teaches a technique for treating hydrocarbon wells, using two separate

1 propellant ignition phases. A gas generator comprising a propellant charge, housed  
2 in a carrier having many openings, is lowered into the well in-line with the perforated  
3 interval. The gas generator is ignited and produces sufficient energy to breakdown  
4 and clean-out all of the perforations and create micro-fractures originating from the  
5 perforations. This is followed by igniting a second gas generator to inject a  
6 treatment liquid into the formation with energy less than that required to fracture the  
7 formation. No removal of resulting debris is contemplated.

8           A technique to both remove blockage mechanisms, debris and fines  
9 from perforations and to ensure the complete removal of this debris from the  
10 wellbore is needed. Although blockage removal from perforations or fractures is a  
11 by-product of some fracturing procedures, the method and results vary. Jennings  
12 Jr. uses the foam primarily for a different purpose, to extend the fractures and is  
13 limited to the amount of foam produced by the foaming agent. Mohaupt breaks  
14 down debris and cleans-out perforations but does not remove the debris from the  
15 well. Mohaupt also does not use foaming techniques. If blockage debris and fines  
16 are not completely removed from the wellbore, the remaining debris can re-block  
17 perforations, erode production equipment and seals, or plug the outside or the inside  
18 of the production tubing reducing or totally restricting production. Well clean-out  
19 procedures would be repeatedly required at a large expense.

20

## SUMMARY OF THE INVENTION

A process is described for formation treatment or stimulation and which accommodates clean-up of debris associated with the stimulation. In one embodiment, a propellant is ignited adjacent openings to the formation and, substantially immediately thereafter, foam is continuously injected adjacent the openings and circulated up through a wellbore to remove debris from the formation and convey the debris therefrom. The tubing string extends sufficiently above the wellbore at surface to enable lowering of the tubing string and foam discharge port to below the openings for enhanced removal of debris.

In a broad aspect, a process for treating a wellbore having openings in communication with a damaged formation comprises: running in a tubing string into the wellbore to position a propellant carrier adjacent the openings; overbalancing the wellbore to establish hydrostatic pressure on the formation; **igniting** the propellant so as to produce a pressure event and a volume of gas directed into the formation; injecting low density foam through the tubing string and into the wellbore at a location above the propellant carrier so as to reduce the hydrostatic pressure and produce at least some debris from the formation and into the wellbore; and conveying the debris from the wellbore by circulating the foam out of the wellbore at surface until sufficient debris is removed. Typically thereafter the tubing string is then removed. It is preferable to lower the tubing string during foam circulation so as to re-position the location of foam injection below the openings

In another broad aspect, novel apparatus for achieving this process comprises: a tubing string in the casing and extending downhole from surface for

1 positioning a propellant in a propellant carrier adjacent the openings and forming an  
2 annulus between the tubing string and the casing; means for igniting the propellant;  
3 and means, such as a foam discharge port in the tubing string adjacent and above  
4 the propellant, for injecting and circulating foam from an injection location adjacent  
5 the openings, up the annulus and out of the wellbore. More preferably, the tubing  
6 string extends sufficiently above surface to enable lowering the foam discharge port  
7 below the openings for enhanced debris recovery.

8

1                                    BRIEF DESCRIPTION OF THE DRAWINGS

2                                    Figure 1a is a simplified cross-section of a wellbore illustrating  
3                                    apparatus run in on a tubing string for placement of propellant carrier adjacent a  
4                                    formation before ignition;

5                                    Figure 1b illustrates a partial cross-section of an optional arrangement  
6                                    according to Fig. 1a without a lubricator;

7                                    Figure 2a is a simplified cross-section of a wellbore illustrating  
8                                    actuation of the tubing string for ignition and foam circulation;

9                                    Figure 2b illustrates a partial cross-section of an optional arrangement  
10                                   according to Fig. 2b for actuating ignition and foam circulation using pressure-  
11                                   actuation;

12                                   Figures 3a – 3h are a series of schematics of a sequence of events  
13                                   according to one embodiment of the invention; and

14                                   Figure 4 is a flowchart of some steps of an embodiment of the  
15                                   invention according to Figs. 3a-3h.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to Fig. 1a, in a preferred embodiment of the invention, it is desirable to dislodge blockage mechanisms or debris from the wellbore area of a formerly productive interval of an underground formation 10 adjacent openings in a casing 12 of a wellbore annulus or wellbore 13. Herein, openings are referred to as perforations 11 which are to include other alternate openings enabling communication between the wellbore 13 and formation through the casing 12 including screens, and slots for example. Generally, debris is removed by igniting a propellant 16 in the wellbore 13 and then substantially immediately commencing to inject and circulate low density foam to the surface 18 for the removal of resulting debris.

The formation 10 and wellbore 13, which is no longer producing desired or even commercial rates, is prepared for a workover treatment using an embodiment of the present invention. A suitable wellhead configuration comprises a spool 15 having a foam and debris outlet 19 providing communication with the wellbore 13, a blow-out preventor 21 and a pack-off 22 at a wellhead W, and a pup length of tubing 23 with a foam injection inlet 24.

In one embodiment, propellant 16 is ignited with the assistance of a lubricator 30 further comprising lubricator tubing 31, a drop bar 32 and a trigger 33 such as a mechanical release mechanism or valve for temporarily retaining and releasing the drop bar 32 on command. Alternatively, the propellant 16 may be pressure actuated, both embodiments being described in greater detail below.

1                   With reference also to Figs. 3a-3h and Figs. 4a-4c, a candidate well is  
2 selected 100 (Fig. 4a) and a workover string is prepared comprising a tubing string  
3 40 fit at its distal end with a propellant carrier 26 having a firing head (not shown)  
4 and a foam injection means 28 such as a foam discharge port 29 in the tubing string  
5 40 adjacent to and uphole of the propellant carrier 26. The tubing string 40 is made  
6 up with conventional components to assist in establishing a tubing tally and the like.

7                   As shown at Figs. 3a,4a and at 101, the tubing string 40 is lowered into  
8 wellbore 13 such that at 103 the propellant carrier 26 is located across from the  
9 existing perforations 11 communicating with the formation 10 to be treated. Of  
10 course, safe procedures must be used in a workover including proper tubing string  
11 entry techniques. The tubing string 40 is suspended in the wellbore 13 at the  
12 packoff 22, the pup length of tubing 23 is installed, having sufficient length to  
13 manipulate the tubing string 40 from above the perforations to below the  
14 perforations. A lubricator 30 can be installed. The foam injection means 28 can  
15 further comprise a differential fill flow sub (not detailed), employed at the bottom of  
16 the tubing string 40 to exclude debris and the like during running in.

17                   In Figs. 3b,4a and at 104, In no particular order a conventional  
18 wellbore liquid 43 is rapidly added to the wellbore 13 for increasing a fluid level 20  
19 and resulting hydrostatic head to about maximum, sufficiently above the perforations  
20 11 or productive interval, maximizing the head which tends to place the well in an  
21 overbalanced condition. Also the tubing string 40 is filled with liquid, such as  
22 produced water, above the differential fill flow sub. At Figs. 3c,4a, the propellant 16  
23 is ignited and the foam discharge port 29 is opened, as described in process step



1 105. The head of liquid in the tubing string 40 assists in directing the resulting high  
2 pressure event into the formation 10 rather than permitting the energy to escape  
3 uphole along the tubing string.

4 As shown in Fig. 1a, in one embodiment the lubricator 30 temporarily  
5 houses the drop bar 32 and is used to cooperate with the firing head to initiate  
6 ignition of the propellant 16. The fill sub remains sealed from the wellbore 13,  
7 excluding liquids therefrom, until actuated by the falling drop bar 32. As shown in  
8 Fig. 2a, in the context of a lubricator 30, the trigger 33 is actuated for releasing the  
9 drop bar 32. The drop bar 32 actuates a firing head which ignites the propellant 16.  
10 In Fig. 4b and at 105 and 106, should a misfire occur, the drop bar 32 is fished out  
11 and re-set to repeat at 104. As well as igniting the propellant 16, the drop bar 32  
12 also actuates the fill sub for opening the foam discharge port 29. In an alternate  
13 embodiment, the firing head is pressure actuated. Accordingly, there is no need for  
14 a drop bar nor a lubricator. Additionally, the foam injection means 28 comprises the  
15 foam discharge port 29 fit with a pressure-actuated plug. In Fig. 2b, in the context of  
16 a pressure-actuated firing head, a pump 44 is employed to pressurize the tubing  
17 string 40 to a first pressure for initiating a pressure-actuated firing head. Unless the  
18 pressure-actuated plug is already opened due to the propellant ignition, further  
19 pumping is applied and pressure increase releases the pressure-actuated plug at  
20 the foam discharge port 29 enabling communication with the wellbore 13.

21 In Figs. 3c,4a, and at 104, hydrostatic pressure of the liquid 43 in the  
22 wellbore 13 as well as that of the liquid in the tubing 40 assists in directing the  
23 resulting high pressure event into the formation 10 rather than wasting the energy

1 uphole. Rapidly expanding gas and pressure 45 assists in removing blockages from  
2 the formation 10 about the perforations 11.

3           At Figs. 3d,4b and at 107 and substantially immediately after igniting  
4 the propellant 16, conventional low density foam 46 is injected into the wellbore 13  
5 through the foam discharge port 29. The circulation of foam 46 is established  
6 through the injection inlet 24 at the pup length of tubing 23 at surface and wellbore  
7 liquid 43 and foam 46 are recovered from the wellbore 13 through the spool 15 at  
8 surface. The foam 46 dramatically lowers the hydrostatic head on the formation 10  
9 stimulating production of formation fluids. The wellbore 13 is now exposed to larger  
10 formation pressure and inflow. As a result, debris is produced into the wellbore 13.  
11 Additionally, circulation of the foam 46 and its relatively high viscosity aid in  
12 conveying the produced debris up the wellbore 13 to the surface. The foam 46 is  
13 circulated and transports wellbore liquid 43 and debris to the surface 18 where it is  
14 removed with the foam 46. Circulation of foam 46 ensures the capture and removal  
15 of substantially all produced debris, as the low density foam 46 rises to the surface  
16 18.

17           At Figs. 3e,4b and at 108, when circulating foam 46 and for more  
18 effective removal of debris, the tubing string 40 is slowly lowered so that foam  
19 discharge port 29 is below the perforations 11. The ability to lower the tubing string  
20 40 and the depth it can be lowered is predetermined by the pup length of tubing 23  
21 above the packoff seal 22. In Fig. 4c and at 109, it can be desirable in some  
22 instances to stroke, or lower and raise, the tubing string 40 periodically to prevent  
23 lodging of the debris and sand flowing into the wellbore 13 between the tubing string

1 40 and well casing 12. This action is recommended to continue until sufficient debris  
2 has been successfully removed.

3 At Figs. 3f,4c once sufficient debris has been removed, the formation  
4 10 is sufficiently rejuvenated so as to re-establish useful inflow. At 110, the tubing  
5 string 40 then raised to elevate the propellant carrier 26 above the perforations 11  
6 and, at 111, one of a variety of techniques can be used to apply sufficient hydrostatic  
7 head to kill the well before safely pulling the tubing string 40 from the wellbore 13 at  
8 Figs. 3g,4c.. Typically the methodology for killing the well is tailored to the particular  
9 well and can include simply diminishing foam circulation or circulating air to allow  
10 formation fluid 47 production to fill the annulus 13 and kill the well or more  
11 aggressively to load up with a suitable wellbore liquid 43.

12 At Figs. 3h,4c, and as an objective of rehabilitating the formation 10, a  
13 production string 50 with pump 51 can be run in to re-establish production from the  
14 treated well.

15 Note that propellant carriers and foam formulations are known and  
16 include those set forth in Jennings Jr. US Patent 4,617,997.

17 As suggested in Fig. 4a at 100, some wells are better candidates than  
18 others for this process, and while this process was developed for the criteria  
19 described below, is not limited to these applications:

20       ▪ The well would have a shut-in fluid level, or low cumulative  
21 production, to indicate some recoverable reserves are still in place;

- 1                   ▪       The well would have exhibited a dramatic, or catastrophic,  
2 decline in production, indicating a blockage mechanism has occurred and the  
3 decline rate is not natural depletion;
- 4                   ▪       Offset wells where previous re-perforating, and propellant  
5 stimulation operation has provided incremental production, even briefly, where the  
6 increased production may sustain due to the increased depth of stimulation from the  
7 propellant or removal of the debris by the stable foam operation;
- 8                   ▪       Wells with diagnosed shale collapse are excellent candidates  
9 due to suspicion of the presence of large particulate debris and suspicions that such  
10 deposits are a distance from the wellbore; and
- 11                  ▪       This method is further recommended in cases where less  
12 aggressive work over techniques have failed, or have failed to sustain increased  
13 production.  
14